Long distance contribution to $B^- \to K^- K^- \pi^+$, - a searching ground mode for new physics

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ABSTRACT

The decay $B^- \to K^- K^- \pi^+$ has been sugested as a test for minimal supersymmetric standard model and for supersymmetric models with R-parity violating couplings, in view of its extreme smallness in the standard model. We calculate two long distance contributions to this decay, that associated with DD and $D\pi$ intermediate states and that induced by virtual D, π mesons. The branching ratio due to these contributions is 6×10^{-12}, which is somewhat smaller than the standard model short distance result, leaving this decay free for the search of new physics.

The standard model (SM) of strong and electroweak interactions is presently in very good shape. The experimental data agree with SM and this continuing success is somewhat paradoxically, a principal factor in the intensive search for physics beyond the standard model. This search is conducted nowadays in various sectors of particles phenomena. Among these, rare b decays is considered to provide good opportunities for discovering new physics beyond SM [1].

Among the rare decays studied so far $b \to s\gamma$ plays prominent role. The measured rate in two different experiments is $Br(b \to s\gamma) = [3.15 \pm 0.35(stat) \pm 0.32(syst) \pm 0.26(mod)] \times 10^{-4}$ [2] and $Br(b \to s\gamma) = [3.11 \pm 0.80(stat) \pm 0.72(syst)] \times 10^{-4}$ [3], to be compared with the latest theoretical calculations within the SM giving $Br(B \to X_s\gamma) = (3.32 \pm 0.30) \times 10^{-4}$ [4]. The agreement with SM is impresive and it is doubtful that a deviation could be detected, even when the above figures are improved. This, in view of the fact that long-distance (LD) contributions are also present; although more difficult to calculate with good accuracy, the existing estimates concur that these are approximately $(5-10)\%$ of the short-distance (SD) amplitude [5].

An alternative approach to the identification of virtual effects from new particles in b decays like $b \to s\gamma$ and $b \to sl^+l^-$ is the consideration of rare decays which are of negligible strength in SM. In such cases the mere appearence of the decays at a rate much larger than it is possible in SM would be a clear sign of new physics.

Recently, the decays $b \to ss\bar{d}$, $b \to dd\bar{s}$ were proposed [6] as ideal prototypes of the latter method. As shown in Ref. [6], the $b \to ss\bar{d}$ is mediated in the SM by box-diagram and its calculation results in a branching ratio nearly of 10^{-11}, the exact value depending on the relative unknown phase between t, c contributions in the box. The $b \to dd\bar{s}$ branching ratio is even smaller by a factor of about 10^2, due to the relative $|V_{td}/V_{ts}|$ factor in the amplitudes. The authors of ref. [6] have also calculated the $b \to ss\bar{d}$ transition in various "beyond the SM" models. It appears that for certain plausible values of the parameters, this decay may proceed with a branching ratio of $10^{-8} - 10^{-7}$ in the minimal supersymmetric standard model and in two Higgs doublet models.

Moreover, when one considers supersymmetric models with R-parity violating couplings, it turns out that the existing bounds on the involved couplings of the superpotential do not provide at present any constraint on the $b \to ss\bar{d}$ mode [6]. It has been pointed out in Ref. [6] that the hadronic chan-

nels most suitable for the search of the $b \to ss\bar{d}$ transition are the $\Delta S = 2$ decays $B^- \to K^- K^- \pi^+$ or $\bar{B}^0 \to K^- K^- \pi^+ \pi^+$. The appropriate exclusive channel for $b \to dd\bar{s}$ transition would be $B^- \to K^+ \pi^- \pi^-$. At present there is no published experimental limits on these modes.

In the analysis of Ref. [6] only the short-distance contributions were considered in detail. However, it is well known that long-distance contributions which are associated with low-lying intermediate hadronic states [7] are also present in particle transitions. As we mentioned above, such contributions to $B \to X_s \gamma$ are rather small. However, each specific decay mode requires the estimation of its LD contribution; this is imperative, since only when a trustworthy estimate of such contributions is available one may proceed to compare the specific transition to the theoretical SM treatment or use it for revealing new physics. This necessity is best exemplified by known occurences in K - physics [8]: in some decays like $K^+ \to \pi^+ \pi^0 \gamma$, $K^+ \to \pi^+ l^+ l^-$ the SD contribution is obscured by LD contributions while for $K_L^0 \to \pi^0 \nu \bar{\nu}$, $K^+ \to \pi^+ \nu \bar{\nu}$, the LD contributions are considerably smaller than the standard model short-distance amplitude [9]. The calculation of long-distance contributions to a specific process is not based on a well-defined theoretical procedure. Clearly, the intermediate states are the main contributions to this part of the amplitude. However, the technique of their inclusion, as well as the choice of relevant states will influence the final result. We shall rely on the accumulated experience from the treatment of long-distance contributions to various processes, like $K - \bar{K}$ transition [7], $\bar{D} - D$ transition [10], $K^+ \to \pi^+ \nu \bar{\nu}$ [11], $B \to X_s \gamma$ [5] and $B_s \to \gamma\gamma$ [12] decays, in order to formulate our approach to the $B^- \to K^- K^- \pi^+$ process at hand.

We include two contributions in the calculation of the long distance amplitude $B^- \to K^- K^- \pi^+$: (I) the box diagram, shown in Fig. 1, which is essentially the LD analog of the SD calculation in the standard model [6] of the $b \to ss\bar{d}$ transition. (II) the contribution of virtual "D^0" and "π^0" mesons, via the chain $B^- \to K^-$"D^0"("π^0"$) \to K^- K^- \pi^+$. This contribution arises as a sequence of two $\Delta S = 1$ transitions and may lead to final $K^- K^- \pi^+$ state as well. It is therefore necessary to have an estimate of its relevance vis - à - vis the "direct" $\Delta S = 2$ transition. Let us consider firstly the amplitude arising from (I). The two diagrams (a) and (b) express the Glashow - Iliopoulos - Maiani symmetry, so that the decay amplitude vanishes in the limit $m_c = m_u$ ($m_D = m_\pi$). Since each diagram contains two W's, it is related to several semileptonic processes with one virtual meson. Thus diagram

(a) relates to $D^0 \to K^- e^+ \nu_e$, $B^- \to D^0 e^- \bar{\nu}_e$ and $D^0 \to \pi^+ e^- \bar{\nu}_e$ involving the product $V_{cb} V_{cs}^* V_{cd} V_{cs}^*$ and diagram (b) relates $D^0 \to K^- e^+ \nu_e$, $B^- \to D^0 e^- \bar{\nu}_e$, $K^- \to \pi^0 e^- \bar{\nu}_e$ and $\pi^+ \to \pi^0 e^+ \nu_e$ involving the product $V_{cb} V_{cs}^* V_{ud} V_{us}^*$.

The transition probabilty is given by

$$
\begin{aligned}
< K^- K^- \pi^+ | \mathcal{S} | B^- >_{box} = & \left(\frac{ig}{2\sqrt{2}}\right)^4 V_{cb} V_{cs}^* V_{cd} V_{cs}^* \int d^4 q_1 d^4 q_2 d^4 Q_2 d^4 Q_1 \\
& \{ \delta^4(Q_1 + q_2 - k_2) \delta^4(p_B - q_1 - Q_1) \delta^4(Q_2 - p_\pi - q_2) \delta^4(q_1 - Q_2 - k_1) \\
& < D^0 | (\bar{c} b)^\nu | B^- > \frac{i}{q_1^2 - m_D^2} < K^- | (\bar{s} c)^\alpha | D^0 > \frac{-i(g_{\nu\alpha} - Q_{1\nu} Q_{1\alpha}/M_W^2)}{Q_1^2 - M_W^2} \\
& \frac{-i(g_{\mu\beta} - Q_{2\mu} Q_{2\beta}/M_W^2)}{Q_2^2 - M_W^2} [< K^- | (\bar{s} c)^\mu | D^0 > \frac{i}{q_2^2 - m_D^2} < \pi^+ D^0 | (\bar{c} d)^\beta | 0 > \\
& - < K^- | (\bar{s} u)^\mu | \pi^0 > \frac{i}{q_2^2 - m_\pi^2} < \pi^+ \pi^0 | (\bar{u} d)^\beta | 0 >] \\
& + \delta^4(Q_1 - q_2 - k_2) \delta^4(p_B - q_1 - Q_1) \delta^4(Q_2 - p_\pi + q_2) \delta^4(q_1 - Q_2 - k_1) \\
& < D^0 | (\bar{c} b)^\nu | B^- > \frac{i}{q_1^2 - m_D^2} < K^- | (\bar{s} c)^\mu | D^0 > \frac{-i(g_{\nu\alpha} - Q_{1\nu} Q_{1\alpha}/M_W^2)}{Q_1^2 - M_W^2} \\
& \frac{-i(g_{\mu\beta} - Q_{2\mu} Q_{2\beta}/M_W^2)}{Q_2^2 - M_W^2} [< K^- \bar{D}^0 | (\bar{s} c)^\alpha | 0 > \frac{i}{q_2^2 - m_D^2} < \pi^+ | (\bar{c} d)^\beta | \bar{D}^0 > \\
& - < K^- \pi^0 | (\bar{s} u)^\alpha | 0 > \frac{i}{q_2^2 - m_\pi^2} < \pi^+ | (\bar{u} d)^\beta | \pi^0 >] + (k_1 \leftrightarrow k_2) \}, \quad (1)
\end{aligned}
$$

where $(\bar{q}_j q_i)^\alpha$ stands for $\bar{q}_j \gamma^\alpha (1 - \gamma_5) q_i$, while the rest of the notation is defined in Figure 1. The first part comes out from the diagrams on Figure 1, while the second results from the crossed diagrams. The calculation of (1) depends on the matrix elements $< D^0 | (\bar{c} b)^\nu | B^- >$, $< K^- | (\bar{s} c)^\mu | D^0 >$, $< \pi^+ | (\bar{c} d)^\beta | \bar{D}^0 >$, $< K^- | (\bar{s} u)^\mu | \pi^0 >$ and $< \pi^0 | (\bar{u} d)^\beta | \pi^- >$. Since only pseudoscalar states appear, we have to deal with transitions between such states induced by the vector current only,

$$
< P'(p') | \bar{q}_j \gamma^\mu q_i | P(p) > = f_+(q^2)(p^\mu + p'^\mu) + f_-(q^2)(p^\mu - p'^\mu), \quad (2)
$$

which may be rewritten as [13]

$$
\begin{aligned}
< P'(p') | \bar{q}_j \gamma^\mu q_i | P(p) > \quad = & \quad F_1(q^2)\left(p^\mu + p'^\mu - \frac{m_P^2 - m_{P'}^2}{q^2}(p^\mu - p'^\mu)\right) \\
+ & \quad F_0(q^2) \frac{m_P^2 - m_{P'}^2}{q^2}(p^\mu - p'^\mu), \quad (3)
\end{aligned}
$$

where F_1 and F_0 contain the contribution of vector and scalar states respectively and $q^2 = (p-p')^2$. Also, $F_1(0) = F_0(0)$ [13]. For these form factors, one usually assumes pole dominance [11, 13, 14, 15]

$$F_1(q^2) \;=\; \frac{F_1(0)}{1-\frac{q^2}{m_V^2}}; \;\; F_0(q^2) = \frac{F_0(0)}{1-\frac{q^2}{m_S^2}} \tag{4}$$

and in order to simplify, we shall take $m_V = m_S$, from which results $f_-(q^2) = 0$. We shall assume that one can safely take $f_+(q^2) \simeq 1$ [10] and the limit $Q_1^2\,,\, Q_2^2 \ll M_W^2$, which then leads to a more tractable expression for the real part of the amplitude

$$\begin{aligned}
\mathcal{A}_r^{box}(B^-(p_B) \to K^-(k_1)K^-(k_2)\pi^+(p_\pi)) = \frac{G^2}{16\pi^4} V_{cb}V_{cs}^* V_{cd}V_{cs}^* \int d^4q_1 \\
\{\frac{1}{q_1^2 - m_D^2}\frac{1}{(q_1-k_1-p_\pi)^2 - m_D^2}[(-m_B^2 + 2k_2\cdot p_B)(m_K^2 + 2k_1\cdot p_\pi) \\
+q_1^2(m_K^2 + 2k_1\cdot p_\pi + m_B^2 - 2k_2\cdot p_B) + 2k_2\cdot q_1(m_K^2 + 2k_1\cdot p_\pi) \\
+2p_\pi\cdot q_1 2k_2\cdot q_1 - 2k_2\cdot q_1 q_1^2 + 2p_\pi\cdot q_1 q_1^2 + 2p_\pi\cdot q_1(-m_B^2 + 2p_\pi\cdot p_B) - q_1^4] \\
-\frac{1}{q_1^2 - m_D^2}\frac{1}{(q_1-k_1-p_\pi)^2 - m_\pi^2}[(-m_B^2 + 2k_2\cdot p_B)(m_K^2 + 2k_1\cdot p_\pi) \\
+q_1^2(m_K^2 + 2k_1\cdot p_\pi + m_B^2 - 2k_2\cdot p_B) + 2k_2\cdot q_1(m_K^2 + 2k_1\cdot p_\pi) \\
+2p_\pi\cdot q_1 2k_2\cdot q_1 - 2k_2\cdot q_1 q_1^2 + 2p_\pi\cdot q_1 q_1^2 + 2p_\pi\cdot q_1(-m_B^2 + 2p_\pi\cdot p_B) - q_1^4] \\
+(k_1 \leftrightarrow k_2)\},
\end{aligned} \tag{5}$$

where $G = \sqrt{2}g^2/(8M_W^2)$. The separate contributions of DD and $D\pi$ intermadiate states diverge as fourth power. However, the GIM cancellation acts in such a way as to decrease the degree of divergence and finally the integral in (5) will give a quadratic divergence. Similar situations were encountered in previous LD calculations [7, 11]. We note that the explicit inclusion of the pole-type form factors for $f_+(q^2)$ would reduce the degree of divergence, in such a case, however, the evaluation of the integrals becomes very cumbersome and this effort is not justifed since as it will turn out the contribution of the real part is essentially negligible in comparison to that provided by the imaginary part. The integrals in (5) are calculated by using Feynman parametrization. The final result for the decay rate is

$$\Gamma(B^- \to K^-K^-\pi^+) \;=\; \frac{1}{2(2\pi)^3 32 m_B^3}\int_{(m_\pi+m_K)^2}^{(m_B-m_K)^2} ds_2 \int_{(s_1)_1}^{(s_1)_2} ds_1 |\mathcal{A}|^2, \tag{6}$$

where

$$
\begin{aligned}
(s_1)_{1,2} &= m_K^2 + m_\pi^2 - \frac{1}{2s_2}[(s_2 - m_B^2 + m_K^2)(s_2 + m_\pi^2 - m_K^2) \\
&\pm \lambda^{1/2}(s_2, m_B^2, m_K^2)\lambda^{1/2}(s_2, m_\pi^2, m_K^2)]
\end{aligned}
\tag{7}
$$

and $\lambda(a,b,c) = a^2 + b^2 + c^2 - 2ab - 2ac - 2ab$. The $\mathcal{A}_r^{box}$ denotes the leading term of the amplitude, which results after using the primitive cut-off regularization:

$$
\mathcal{A}_r^{box}(B^- \to K^- K^- \pi^+) \simeq G^2 V_{cb} V_{cs}^* V_{cd} V_{cs}^* \frac{1}{16\pi^2} \Lambda^2 (m_D^2 - m_\pi^2). \tag{8}
$$

There is obviously the uncertainty in the value to be taken for Λ. The momentum in the box cannot exceed m_B, and by taking $\Lambda \simeq 10$ GeV we obtain

$$
BR(B^- \to K^- K^- \pi^+)_{(r)}^{(box)} \simeq 8 \times 10^{-15} \tag{9}
$$

for the real part of this contribution, using $\Gamma(B^- \to all) = 4 \times 10^{-13}$ GeV [16].

Turning now to the imaginary part of the $B^- \to K^- K^- \pi^+$ amplitude provided by the DD and $D\pi$ intermediate states, it is given by

$$
\begin{aligned}
&\mathcal{A}_i^{box}(B^- \to K^- K^- \pi^+) = -\frac{G^2}{32\pi^2} V_{cb} V_{cs}^* V_{cd} V_{cs}^* \\
&\int d^4 q_1 \delta(q_1^2 - m_D^2)[\delta((q_1 - k_1 - k_2)^2 - m_D^2) - \delta((q_1 - k_1 - p_\pi)^2 - m_\pi^2)] \\
&\{-q_1^4 + -2k_2 \cdot q_1 q_1^2 + 2p_\pi \cdot q_1 q_1^2 + q_1^2(m_K^2 + 2k_1 \cdot p_\pi + m_B^2 - 2k_2 \cdot p_B) \\
&+2p_\pi \cdot q_1 2k_2 \cdot q_1 + 2p_\pi \cdot q_1(-m_B^2 + 2k_2 \cdot p_B) \\
&+2k_2 \cdot q_1(m_K^2 + 2p_\pi \cdot k_1) + (-m_B^2 + 2k_2 \cdot p_B)(m_K^2 + 2k_1 \cdot p_\pi) \\
&+(k_1 \leftrightarrow k_2)\}.
\end{aligned}
\tag{10}
$$

Introducing now $s_1 = (p_B - k_1)^2 = (k_2 + p_\pi)^2$ and $s_2 = (p_B - k_2)^2 = (k_1 + p_\pi)^2$ one arrives at

$$
\begin{aligned}
&\mathcal{A}_i^{box}(B^- \to K^- K^- \pi^+) = -\frac{G^2}{32\pi^2} V_{cb} V_{cs}^* V_{cd} V_{cs}^* \\
&\times\{F(m_D^2, s_1, s_2) - F(m_\pi^2, s_1, s_2) + (s_1 \leftrightarrow s_2)\},
\end{aligned}
\tag{11}
$$

with

$$F(m_P, s_1, s_2) = \frac{\lambda^{1/2}(m_D^2, m_P^2, s_1)}{m_D^2 - m_P^2 + s_1}$$
$$\{-m_D^4 + m_D^2(2s_1 - \frac{3}{2}m_K^2 - \frac{3}{2}m_\pi^2 - \frac{1}{2}s_2) + (s_1 - m_\pi)(-s_1 + m_K^2)$$
$$+(s_1 \leftrightarrow s_2)\}. \qquad (12)$$

Using the expression (6) for the decay width we find

$$BR(B^- \to K^- K^- \pi^+)^{(box)}_{(i)} \simeq 6 \times 10^{-12}. \qquad (13)$$

We proceed now to estimate the second possibility for a LD part which may lead to a final $K^-K^-\pi^+$ state. This possibility is expressed as two consecutive two-body nonleptonic transitions (see Fig. 2) in which the connecting single particles D^0 and π^0 is virtual. An estimate of this contribution requires the knowledge of the $< B^-|\mathcal{H}_w|K^-"D^0" >$, $< "D^0"|\mathcal{H}_w|K^-\pi^+ >$ amplitudes for virtual D^0, which is lacking. For a virtual π^0 existing estimates for $< "\pi^0"|\mathcal{H}_w|K^-\pi^+ >$ indicate [11] that it is smaller than the physical amplitude in a certain region. We rely in our estimation on the "physical" amplitudes $B^- \to K^-D$, $D^0 \to K^-\pi^+$ [15], keeping in mind that this induces an amount of uncertainty. However, the final numerical results will show that this is of no consequence in the present problem. In the diagram (2b) the D^0 may also be on the mass shell. Therefore, we must exclude in our calculations the region around physical D^0, which represents two $\Delta S = 1$ physical decays, $B^- \to D^0 K^-$ followed by $D^0 \to K^-\pi^+$, since we are pursuing the $B^- \to K^-K^-\pi^+$ outside the resonance region. We shall return to this point below.

The calculation of the virtual D^0 mediated part of the amplitude requires the use of the effective nonleptonic Lagrangian. The part relevant for the present calculation is

$$\begin{aligned} \mathcal{L}_{LD} &= -\frac{G}{\sqrt{2}}\{V_{cb}V_{us}^*[a_1^{(b)}(\bar{c}b)^\mu(\bar{s}u)_\mu + a_2^{(b)}(\bar{c}u)^\mu(\bar{s}b)_\mu] \\ &+ V_{cs}V_{ud}^*[a_1^{(c)}(\bar{c}s)^\mu(\bar{d}u)_\mu + a_2^{(c)}(\bar{c}u)^\mu(\bar{d}s)_\mu] + h.c.\}, \end{aligned} \qquad (14)$$

$V_{q_1q_2}$ are CKM matrix elements and $a_1^{(c)}$, $a_2^{(c)}$, $a_1^{(b)}$ and $a_2^{(b)}$ are effective Wilson coefficients (see Bauer et al., Ref. [15]) at the charm and beauty scales. We

use factorization approximation [15] for the two parts of the $B^- \to K^- K^- \pi^+$ amplitude and the expression obtained in [14] for the $< P_1 P_2 | D >$ transition,

$$M_{<P_1P_2|D>} = \frac{G}{\sqrt{2}} C_{P_1P_2} i f_{P_2} F_0^{D\to P_1}(m_{P_2}^2)(m_D^2 - m_{P_1}^2). \qquad (15)$$

In (15) $C_{P_1P_2}$ contains CKM matrix elements and a Wilson coefficient. By using the explicit form of (15) we have neglected the small contribution from the annihilation part of the amplitude, which is proportional to $a_2^{(b)}$, $a_2^{(c)}$ [14]. The part of the decay amplitude due to the "D^0" pole is then given by

$$\mathcal{A}_{D^0}^{pole}(B^- \to K^- K^- \pi^+) = -\frac{G^2}{2} V_{cb} V_{us}^* V_{cs} V_{ud}^* a_1^{(b)} a_1^{(c)} f_K f_\pi \times F_0^{BD}(m_K^2) F_0^{DK}(m_\pi^2) \frac{(m_B^2 - q^2)(q^2 - m_K^2)}{q^2 - m_D^2 + i m_D \Gamma_D}. \qquad (16)$$

The decay width due to this contribution is given by

$$\Gamma(B^- \to K^- K^- \pi^+) = \frac{1}{2(2\pi)^3 32 m_B^3} |C|^2 |F_0^{BD}(m_K^2) F_0^{DK}(m_\pi^2)|^2 \times \int_{(m_\pi + m_K)^2}^{(m_B - m_K)^2} ds \frac{(m_B^2 - s)^2 (s - m_K^2)^2}{(s - m_D^2)^2 + (m_D \Gamma_D)^2} \frac{1}{s} \lambda^{1/2}(s, m_B^2, m_K^2) \lambda^{1/2}(s, m_\pi^2, m_K^2), \qquad (17)$$

with $C = (G^2/2) V_{cb} V_{us}^* V_{cs} V_{ud}^* a_1^{(b)} a_1^{(c)} f_K f_\pi$, for the resonance in a s channel and the same for the resonance in a crossed channel.

Using for $a_1^{(b)}$, $a_1^{(c)}$, F_0^{DK} and F_0^{BD} the values of Bauer, Stech and Wirbel [15] we calculate the virtual "D^0" contribution by deleting a width of 2Δ around D mass in the s variable. The size of Δ is related to the experimental accuracy of the D - determination in the final $K^- \pi^+$ state. In the various experiments it ranges between 1 and 10 MeV. One should keep in mind that average accuracy of D^0 - mass determination is 0.5 MeV [16]. Thus, in order to delete the physical D^0's one must take at least $\Delta = 1$ MeV. However, we shall check the Δ dependence for a range of values to make sure that our conclusions are not affected.

For $\Delta = 20,\ 5,\ 1,\ 0.1$ MeV we find the nonresonant D^0 contribution to be

$$BR(B^- \to K^- K^- \pi^+)_{(D^0)}^{pole} = (0.31;\ 1.2;\ 6.2;\ 61) \times 10^{-15}. \qquad (18)$$

In all cases the result is much smaller than (13), though one should remember that $\Delta = (1-5)$ MeV is the realistic option. A similar calculation for π^0 intermediate contribution, i.e. $B^- \to K^-{}"\pi^0" \; "\pi^0" \to K^-\pi^+$ yields a value smaller by four orders of magnitude, especially as a result of CKM angles. The pole contribution is therefore considerablly smaller than the LD box contribution calculated with DD and $D\pi$ intermediate states; thus the total branching ratio from all diagrams we included is

$$BR(B^- \to K^-K^-\pi^+)_{LD} \quad = \quad 6 \times 10^{-12}. \tag{19}$$

As a check, we used our $\mathcal{A}^{pole}_{(D^0)}$ amplitude to calculate $B^- \to K^-K^-\pi^+$ as given by decay via a physical D^0 and we find a branching ratio of 7×10^{-6}. This agrees very well with the experimental expectation of $(9.9 \pm 2.8) \times 10^{-6}$, obtained by using $BR(B^- \to D^0K^-) = (2.57 \pm 0.65 \pm 0.32) \times 10^{-4}$ [17] and $BR(D^0 \to K^-\pi^+) = 3.85 \times 10^{-2}$ [16].

A few remarks concerning our approximations. As we mentioned, we have neglected the form factor dependence in the calculation of $\mathcal{A}^{box}_r$. Their inclusion would have decreased the degree of divergence. However, in view of the smallness of the real part of the amplitude, this neglect is of no consequence. A possibly more serious uncertainty is caused by the fact that we used only DD and $D\pi$ intermediate states in the box calculations. Additional intermediate states, all within the physical region could be DD^*, D^*D^*, $D\rho$, $D^*\rho$, $D\eta(\eta')$. We did not consider these states for two main reasons: first, there is no knowledge of the matrix elements and the required form factors involved. Moreover, the inclusion of strongly decaying resonances D^*, ρ as intermediate states is questionable and some of their effects are taken into account by the form factors considered (4). We decided therefore to ignore these contributions, though we are aware of the possibilty that additional intermediate states in Fig. 1 might increase our result by a factor of, say, 2-3. Finally, it is interesting to note that our result, which indicates that the LD contribution in the $B^- \to K^-K^-\pi^+$ decay is smaller or at most comparable to the SM short-distance contribution, fits into the general picture of B decays. This is in contrast to the situation in the strange and charm sectors: in K transitions the two contributions are comparable in some cases, SD dominates in a few decays and LD in many others; in D - transitions LD contributions are generally larger than the SD ones, except for the unusual case of $B_c \to B_u^*\gamma$ decay [18].

To summarize, we have shown that the long - distance contributions to $B^- \to K^- K^- \pi^+$ are smaller in the SM than the short - distance box diagram, and have the branching ratio in a $10^{-12} - 10^{-11}$ range. This is a most welcome feature since it strengthens the suitability of the $B^- \to K^- K^- \pi^+$ decay as an ideal testing ground for physics beyond the standard model, as originally suggested in ref. [6]. We expect that this avenue will be explored experimentally in the near future and we note that the first analysis of this mode has just been completed by the OPAL Collaboration [19] and an upper limit of 1.29×10^{-4} at 90% confidence level has been set for the branching ratio of this decay.

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Figure Captions

Fig. 1. Long distance box-diagram contributions to $B^- \to K^- K^- \pi^+$.

Fig. 2. Pole contributions to the long distance amplitude of $B^- \to K^- K^- \pi^+$, (a) quark picture, (b) hadronic picture.

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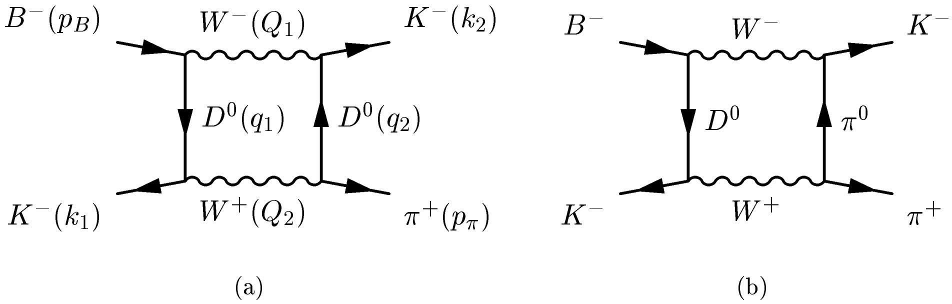
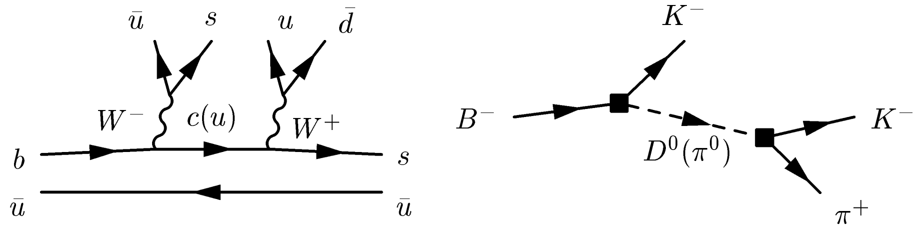


Figure 1: Long-distance box-diagram contributions to $B^- \to K^- K^- \pi^+$.



(a)

(b)

Figure 2: Pole contributions to the long-distance amplitude of $B^- \to K^- K^- \pi^+$. (a) quark picture, (b) hadronic picture.